EPSRC/MOD GR/L04405 **FINAL REPORT**
MODELLING SiGe QUANTUM DEVICES

Summary

This joint EPSRC/MOD research grant was awarded to Prof R A Abram and Dr S Brand of the Department of Physics, University of Durham, to model charge transport in novel devices and quantum structures based on Si and SiGe. The grant provided funds for an HP-C160MHz workstation and one postdoctoral research assistant for three years. A principal objective was the assessment of device designs that could be fabricated using existing growth technology, but which were less conventional in their electronic operation.

A particular example of this was the investigation of the performance of Si-based velocity modulation transistors grown on silicon-on-insulator (SOI) substrates. Velocity modulation was originally suggested as a method of obtaining rapid transistor switching, in which the electron drift velocity, rather than the charge density in the device, is modified by an applied gate bias. The ellipsoidal conduction band valley Monte Carlo simulation that was developed for the modelling was also applied to recent experimental SiGe n-MODFETs and to deep submicron vertical MOSFETs. In addition, the project was intended to provide some theoretical support for experimental studies of the fundamental transport properties of two-dimensional electron gases conducted by Dr D J Robbins and co-workers at DERA (Malvern) and Dr D J Paul et al at the Cavendish Laboratory. In this context, a self-consistent calculation was devised to study low temperature electron transport in Si (on $Si_{0.77}Ge_{0.23}$) wells.

There has been a lack of theoretical work on coupled SiGe quantum well structures, and therefore another Monte Carlo code was developed to study parallel transport for these systems. Such a system was of interest to Cambridge/DERA at the time, and considered to have a potential application as the basis for a tensile-strained Si/SiGe velocity modulation transistor. However, the simulations demonstrated the difficulty in achieving effective operation above 100 K due to the onset of phonon scattering; subsequent calculations suggested that multiple quantum well or step-graded SiGe heterostructures may offer some improvement. The quantum well Monte Carlo transport code was adapted in order to investigate parallel transport and scattering of holes in SiGe/Si and Ge/GeSi quantum wells, and has since been used to try to understand “record mobility” gases in SiGe wells investigated at Warwick University.

The final objective described in the original research proposal was the study of carrier-carrier interactions in group IV two-dimensional systems, in particular, Coulomb drag between closely spaced but segregated electron gases in Si/SiGe. Studies of carrier drag have already proved useful for extracting detailed information about such interactions in III-V low dimensional structures. The Monte Carlo simulation developed for this purpose is close to completion, and we believe that this is the first time that drag effects will have been predicted for non-polar semiconductor heterostructures.

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